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A retrospective methods analysis of semi-automated ICH volume quantification from a selection of the STICH II cohort

Mark D Haley MBBS, Barbara A Gregson PhD, W. Andrew Mould BA, Daniel F Hanley MD, Alexander David Mendelow FRCS(SN)

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Corresponding Author:

Dr. Mark D Haley

Corresponding Author Addresses (Work): Newcastle Neurosurgical Trials Group, Wolfson, Research Centre, Institute of Neuroscience, Newcastle University NE4 5PL

Home: 229 Citadel Road East, Plymouth, PL1 2NG

Tel: +44 191 208 5793

Fax: +44 191 208 5762

Email: m.haley@nhs.net

Group Authors and Affiliations

Neurosurgical Trials Group, Institute of Neuroscience, Newcastle University, Newcastle Upon Tyne, Tyne & Wear, UK. (MDH, BAG, ADM)

Division of Brain Injury Outcomes, Johns Hopkins Medical Institutions, Baltimore, MD, USA. (DFH, AW)

Abstract (240 words)

Background and Purpose

The ABC/2 method for calculating ICH volume has been well validated. However the formula, derived from the volume of an ellipse, assumes the shape of ICH is elliptical. We sought to compare the agreement of the ABC/2 formula to other methods through retrospective analysis of a selection of the STICH II cohort.

Methods

739 scans from 390 patients were selected from the STICH II image archive based on the availability of a CT scan compatible with OsiriX DICOM viewer. ICH volumes were calculated by the reference standard semi-automatic segmentation in OsiriX software and compared to calculated arithmetic methods (ABC/2, ABC/2.4, ABC/3, 2/3SC) volumes. Volumes were compared by difference plots for specific groups: randomisation ICH (n=374), 3-7 day post surgical ICH (n=206), antithrombotic associated ICH (n=79), irregular shape ICH (n=703) and irregular density ICH (n=650). Density and shape were measured by the Barras ordinal shape and density groups (1-5).

Results

The ABC/2.4 method had the closest agreement to the semi automatic segmentation volume in all groups; except for the 3-7 day post surgical ICH group where the ABC/3 method was superior.

Conclusions

Whilst the ABC/2 formula for calculating elliptical ICH is well validated, it must be employed with caution in ICH scans where the elliptical shape of ICH is a false

assumption. We validated the adjustment of the ABC/2.4 method in randomisation, antithrombotic associated, heterogeneous density and irregular shape ICH.

Clinical Trial Registration: ISRCTN22153967.

http://www.isrctn.com/ISRCTN22153967

Introduction

Spontaneous intracerebral haemorrhage (ICH) has a >40% mortality at 30 days[1] and most survivors are left disabled[2]. Initial haemorrhage volume has been well documented as one of the variables for predicting patient outcome[3] and included in the ICH score[4] for predicting patient mortality. Moreover, ICH volume at ictus is an outcome measure and safety criterion for current clinical trials that are hoped to improve patient outcomes in future (MISTIE III, NCT01827046) .[5, 6] Paramount to this work is having an accurate and expedient method for quantifying ICH volume from patient's neuroimaging. Multiple methods exist currently to perform this task, with the ABC/2 method being the most validated.[3] The ABC/2 method approximates ICH volume to the volume of an ellipsoid ($4/3\pi r^3$).[3] In the formula, A = the longest diameter of haemorrhage on the largest slice of haematoma, B = the longest perpendicular diameter to A, C = the depth of haematoma (calculated as the number of slices with haemorrhage multiplied by slice thickness).[3] Whilst the ABC/2 formula has been validated for small to moderately sized elliptical haemorrhages[7,8], there is still debate about the validity of the ABC/2 method in quantifying ICH in the following groups [9-18]:

1. ICH at randomisation in the STICH II trial
2. Day 3-7 post surgical ICH
3. Antithrombotic associated ICH
4. Irregularly sized ICH
5. Heterogeneous density ICH

Studies have validated the following adjustments: ABC/2.4 [16], ABC/3 [17] and 2/3SC (where S= the area of largest haemorrhage on axial slice methods) [9-11, 18] . We

therefore set out to describe the agreement of the methods available to quantify ICH volume, in comparison to a reference standard semiautomatic method (which makes no assumptions about the shape of the haematoma) for calculating ICH volume in these groups from the STICH II[19] cohort.

Methods

Clinical protocol

Participants came from STICH II, an international prospective multi-centre randomised trial of early surgery versus initial conservative therapy for lobar ICH at 78 sites across 27 countries.[19] Full details of original trials ethics and regulatory approval, alongside full inclusion criteria are accessible: http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(13)60986-1/fulltext . Patients in this trial were randomised to early surgery (within 48 hours) or initial conservative therapy. Patients had two scans in this trial, one as part of routine clinical care (diagnostic) pre randomisation and another at between 3 to 7 days later. This study assesses only those patients with open source DICOM viewer (OsiriX Lite v.6.5 32-bit, PIXMEO, Geneva; Switzerland) compatible CT scans, with or without contrast. For each patient, images were received with the thinnest slices provided by CT scan machines using standardised protocols in the recruiting centres. Newcastle University Ethics Committee exempted ethical approval for this study, which was conducted in accordance with the Declaration of Helsinki.

CT Analysis

601 patients were recruited in the STICH II indicating a potential 1202 scans. Patients scans were selected as described in Supplementary Figure I. Approximately 34% (411

scans) were not compatible with the semi automatic segmentation software, using an open source DICOM viewer (OsiriX Lite v.6.5 32-bit, PIXMEO, Geneva; Switzerland) for Mac OS. The final 739 scans were read by one reader (MH) in normally light office conditions using a 13 inch MacBook Pro connected to a 19 inch visual display (DELL P190S) with a Bluetooth connected mouse (MICROSOFT, Notebook mouse 5000). Scans were read randomly, in an order chosen by the computer and paired scans were read blind to each other. All scans were read with window levels set to "CT – Brain" view (window length 50 Hounsfield units (HU), window width 100 HU). The area of ICH on each slice was semi-automatically delineated using the OsiriX "grow region" and "repulsor" tools. Boundaries of 40-80 HU were applied to define blood on CT. Particular attention was paid to avoid the inclusion of the cranium and areas of calcification in volume calculations. After accurately defining the haemorrhage, volumes were calculated by the OsiriX software and the result recorded in cubic centimetres (cm^3). These are defined as region of interest (ROI) volumes.

Four arithmetic methods were tested against ROI for this study (ABC/2, ABC/2.4, ABC/3 and 2/3SC). For each, the largest slice area of haematoma (S) was identified automatically by voxel counts for each slice. Maximum diameter on this slice was measured in centimetres (cm) and recorded as the 'A' measurement. Maximum diameter 90° to 'A' was measured in cm and recorded as 'B'. On regular slice thickness scans 'C' was calculated, in cm, as a product of the number of slices with ICH and the regular slice thickness in cm. Slice thickness ranged from 0.1-1cm in this study. Modified ABC/2 approaches that weight the contribution of slices to the C axis based on the proportion of blood relative to the largest slice, do not respect the 3 Cartesian axes fundamental to the ABC/2 method and are not recommended.[7]

Arithmetic (e.g. ABC/2) volumes were not simultaneously calculated to limit bias. Shape and density measures from each haematoma were measured by one reader (MH) as ordinal variables using the Barras et al.[20] method on the largest slice of haemorrhage, where each point adds an additional shape irregularity or density heterogeneity. Categories 1 and 2 were combined and defined as regular shape or homogenous density and 3 to 5 were combined and defined as irregular or heterogeneous. The antithrombotic associated ICH group was based on the original study data, with 79 patients on one or more of anticoagulants, antiplatelets or thrombolytics premorbidly. Postoperative ICH was defined as any ICH remaining radiologically after a surgical procedure (decompression and/or complete evacuation). Particular attention was paid in these studies not to include any areas of the cranial bone or blood present within the intraventricular, subarachnoid, subdural, extra dural or extra cranial spaces. In the postoperative CT scan, all intracerebral haematoma was included. Scans were examined and measured at random from the image archive. Randomisation scans and 3-7 day scans were analysed separately as they presented different issues. In particular a large number of 3-7-day scans were post procedure and if there was no ICH remaining (volume equal to zero) they were excluded.

Statistical Analysis

Differences in patient and scan characteristics between STICH II and the selected groups were assessed (Table I and II). Difference plots for ICH volume (Figures 1-4 and Supplementary Figure III) show arithmetic method minus semi-automated method, versus arithmetic mean volume. Using the approach of Bland and Altman, linear regression of residuals against mean volume was employed to account for the variations in volume difference with volume magnitude.[21] 95% regression based limits of agreement are demonstrated. The fisher's exact test was used to compare

proportions of scans within specified categories. All measures were rounded to 2 decimal places. The Authors declare that all supporting summary data is available within the article. The manuscript complies with the American Heart Association Journals' Transparency and Openness (TOP) guidelines.

Results

Summary characteristics

Patients at baseline were well matched with the exception of the antithrombotic associated ICH group (Table 1). This group had a tendency to be older and have more comorbidities. Scans characteristics (Table 2) showed an interesting propensity for right sided and deep haemorrhages in the antithrombotic associated group. Moreover there were a greater number of frontal and occipital haemorrhages in this group, with proportionately less temporal and parietal haematomas. ROI volumes in this group were large, perhaps unsurprising due to premorbid antithrombotic use. Intraventricular haemorrhage was most common in the antithrombotic associated and post surgical group.

ICH at Randomization

374 scans at randomization were included in this analysis. Difference plots (figure 1) revealed that the ABC/2.4 method (B) had the smallest slope (y=0.10x-3.64; 95% CI of intercept +13.71, -20.99) with the 2/3SC method (D) having the smallest 95% limits of agreement (y=0.20x-3.12, +9.98, -16.22). The ABC/2 method (A) was inferior to these two methods (y=0.29x-4.23, +14.6, -23.07) whilst the ABC/3 method (C) underestimated ICH volume significantly (y= -0.10x-3.64, +13.71, -20.99). Agreement to the semi-automatically segmented (ROI) volume was also assessed in

the randomization group by looking at volumes calculated ≤ 5mls or ≤ 20% of that of their ROI volume (Supplementary Figure II), as used by Webb et al.[15]. In this analysis, the ABC/2.4 and 2/3SC methods performed significantly ($p<0.0001$) better than the ABC/2 or ABC/3 method in both categories. There was a trend but not statistical significance to supporting ABC/2.4 as the most accurate method for categorizing scans within 20% of ROI volume ($p=0.0723$).

Post-operative ICH

206 post-operative scans were included in this study (figure 2). The ABC/3 method (C) had the smallest slope ($y=0.06x$-0.65, +12.53, -13.84), followed by ABC/2.4 method (B) ($y=0.29x$-0.82, +13.72, -15.48) and the 2/3SC method (D) ($y=0.31x$-0.14, +10.47, -10.75). The ABC/2 method (A) had the largest slope and 95% limits in this group ($y=0.47x$-0.97, +14.75, 16.69).

Antithrombotic associated ICH

Antithrombotic associated ICH is more frequently irregular in shape and therefore more prone to ICH volume estimation error.[10, 19] 79 patients at randomization were included taking one or more of an anticoagulant, antiplatelets or thrombolytics (Table 1). Of these: 24/79 (30.38%) were taking only an anticoagulant, 42/79 (53.16%) were taking only an antiplatelet and 0 (0%) patients were taking only thrombolytic. 8 (10.13%) patients were taking an anticoagulant and an antiplatelet and 4 (5.06%) patients were on anticoagulation with a thrombolytic. 0 (0%) were on an antiplatelet and thrombolytic. 1 (1.27%) patient was taking all 3 medications described above. The ABC/2.4 method (B) had the closest agreement ($y=0.03x$-1.33, +18.84, -21.50) (Figure 3). The 2/3SC method (D) followed ($y=0.13x$-1.30, +11.56, -14.15) with the smallest limits of agreement. The ABC/2 method (A) was inferior ($y=0.22x$-1.87,

+20.10, -23.85). The ABC/3 method (C) was found to considerably underestimate ICH volume in this group (y=-0.20x-0.75, +17.20, -18.71).

Irregular shaped ICH

703 scans were included in this study that were classified as irregular shape on the largest slice of haemorrhage using the Barras ordinal groups 3-5 (See Table 2). 13.37% (94) were group 3, 24.75% (174) were group 4 and 61.88% (435) were group 5. Agreement was greatest for the ABC/2.4 method (y=0.08x-1.2, +16.08, -18.48) and the 2/3SC method (y=0.17x-0.74, +12.69, -14.17) (Figure 4). ABC/3 underestimated ICH volume (y=-0.15x-0.88, +14.54, -16.31) whilst ABC/2 overestimated ICH volume (y=0.27x-1.49, +17.29, -20.27).

Heterogeneous density ICH

650 scans were classified as having heterogeneous density on largest slice of haemorrhage using the Barras ordinal groups 3 to 5. 23.85% (155) were group 3, 17.54% (114) were group 4 and 58.62% (381) were group 5 (Table 2). Difference plots for ICH volume (Supplementary Figure III) showed a similar pattern for irregular density haematomas as irregular shape haematomas with ABC/2.4 (y=0.08x-1.18, +16.62, -18.98) and 2/3SC (y=0.17x-0.76, +13.20, -14.71) having greater agreement than ABC/2 (y=0.27x-1.48, +17.87, -20.82) and ABC/3 (y=-0.15x-0.85, +15.04, -16.74).

Discussion

This study used the validated OsiriX ROI method as the reference standard against which to evaluate other methods of ICH volume estimation. We have validated the use of the ABC/2.4 method for a broad group of spontaneous supratentorial ICH. The

ABC/2.4 method showed the greatest agreement for: randomization ICH volume, antithrombotic associated-, irregularly shaped- and heterogeneous density haemorrhages. This finding challenges the use of the ABC/2 method, having poorer agreement to ABC/2.4. Indeed the ABC/2 method was also inferior to the 2/3SC method. However, the 2/3SC method relies on accurate measurement of the largest axial area of heamorrhage (cm^2) and requires segmentation software for calculation. The ABC/3 method significantly underestimated haemorrhage in all but the 3-7-day post surgical group. It is interesting that the ABC/3 performed particularly poorly in this study with antithrombotic associated haemorrhages. This is contrary to Huttner et al. who demonstrated closer agreement between planimetry and ABC/3 than with ABC/2 for irregular warfarin-related haemorrhages.[17] It must be stated that our sample size in this group of antithrombotic associated ICH was small (n=79) and our patient group were on a combination of anticoagulants, anti-platelets and thrombolytics. However this study did find the ABC/3 method had the closest agreement for measuring postoperative ICH volume. This finding has implications for volume reduction clinical trials in ICH, when post intervention ICH volume is an important outcome measure and sa1fety criterion. Its clinical implication is potentially useful in patients who require re-imaging following surgical evacuation. It is hypothesized by the authors that the increase in denominator seeks to account for 3-7 day ICH being less elliptical in shape, with any residual haematoma likely to form in a non-elliptical shape. This is supported by analysis of matched scans from pre- and post-intervention showing a non statistically significant trend towards increasing Barras shape and a significant trend towards decreasing Barras density at 3-7 days (Supplementary Table I).

There are several limitations to the work presented above, firstly

there was a selection bias to scans in the STICH II image archive that were compatible with OsiriX image viewer, this meant that more scans were from patients who had been recruited from ‘Western centres”, patients who had their initial scan at a remote centre were less likely to have compatible scans. Scans were read by one reader (MH) after a period of training in an experienced ICH imaging laboratory, and as such there are no intra- or inter-rater reliability statistics for this patient selection. Comparison to randomization ABC/2 volumes published in STICH II is not possible due to different selection criteria. The Barras Shape and Density are limited by only assessing the largest slice of haemorrhage and a “ceiling effect” with a maximum score of five.

Conclusion

In conclusion this study has validated the ABC/2.4 method for accurately calculating ICH volume across a number of specified groups relevant to clinical practice. This finding challenges the routine use of the ABC/2 for all but the simplest ellipsoid haemorrhages. The ABC/3 method was found to be particularly accurate for calculating post surgical ICH volumes.

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Conflict of Interest/Disclosures

MH declares no conflict of interest and no disclosures.

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Figure Legends

1. Difference plots comparing ICH volume at randomization measured by ROI with ABC/2 (A) ABC/2.4 (B), ABC/3 (C) and 2/3SC (D). Data includes the first eligible scan for each patient in the STICH II trial. Linear regression of volume difference on mean volume: (A) y=0.29x-4.23, (B) y=0.10x-3.64, (C) y=-0.13x-2.97, (D) y=0.20x-3.12. 95% confidence intervals constructed by linear regression of residuals: (A) y=0.29x+14.60, y=0.29x-23.07 (B) y=0.10x+13.71, y=0.10x-20.99, (C) y=-0.13x+12.54, y=-0.13x-18.47 (D) y=0.20x+9.98, y=0.20x-16.22
2. Difference plots comparing ICH post-surgical volume 3-7 day measured by ROI with ABC/2 (A) ABC/2.4 (B), ABC/3 (C) and 2/3SC (D). Data includes the post-operative eligible scan for each patient in the STICH II trial. Linear regression of volume difference on mean volume: (A) y=0.47x-0.97, (B) y=0.29x-0.82, (C) y=0.06x-0.65, (D) y=0.31x-0.14. 95% confidence intervals constructed by linear regression of residuals: (A) y=0.47x+14.75, y=0.47x-16.69 (B) y=0.29x+13.72, y=0.29x-15.48, (C) y=0.06x+12.53, y=0.06x-13.84 (D) y=0.31x+10.47, y=0.31x-10.75
3. Difference plots comparing ICH volume for patients with antithrombotic associated ICH measured by ROI with ABC/2 (A) ABC/2.4 (B), ABC/3 (C) and 2/3SC (D). Data includes the first eligible scan for each patient in the STICH II trial. Linear regression of volume difference on mean volume: (A) y=0.22x-1.87, (B) y=0.03x-1.33, (C) y=-0.20x-0.75, (D) y=0.13x-1.3. 95% confidence intervals constructed by linear regression of residuals: (A) y=0.22x+20.10, y=0.22x-23.85 (B) y=0.03x+18.84, y=0.03x-21.50, (C) y=-0.20x+17.20, y=-0.20x-18.71 (D) y=0.13x+11.56, y=0.13x-14.15

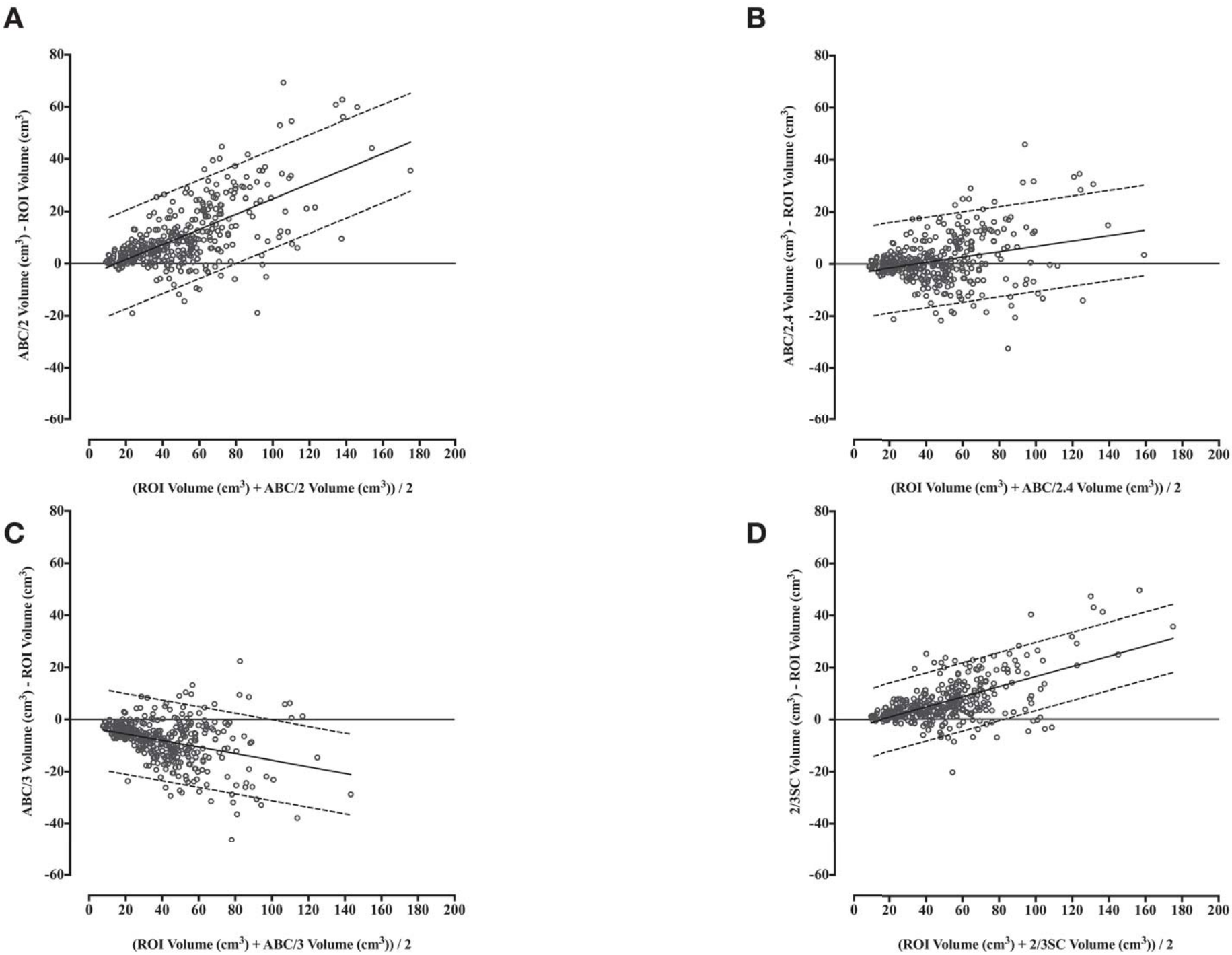
4. Difference plots comparing ICH volume for scans with Barras Shape 3-5 by ROI with ABC/2 (A) ABC/2.4 (B), ABC/3 (C) and 2/3SC (D). Linear regression of volume difference on mean volume: (A) y=0.27x-1.50, (B) y=0.08x-1.20, (C) y=-0.15x-0.88, (D) y=0.17x-0.75. 95% confidence intervals constructed by linear regression of residuals: (A) y=0.27x+17.87, y=0.27x-20.82 (B) y=0.08x+16.08, y=0.08x-18.48, (C) y=-0.15x-16.31, y=-0.15x+14.54 (D) y=0.17x+12.69, y=0.17x-14.17

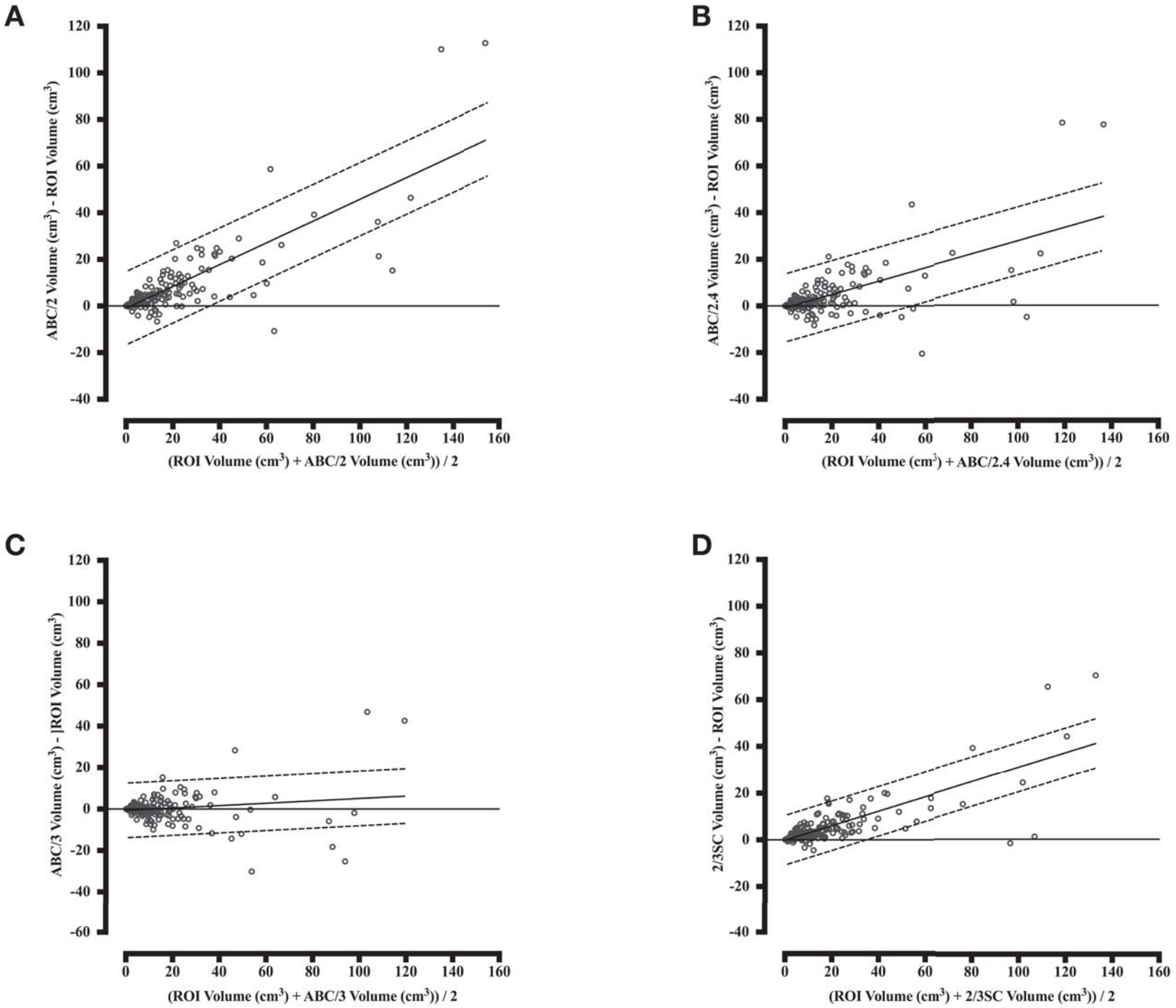
Table 1 Characteristics of included patients. Data are mean (Standard Deviation-SD), median (Interquartile Range-IQR, Range) or frequency (%).

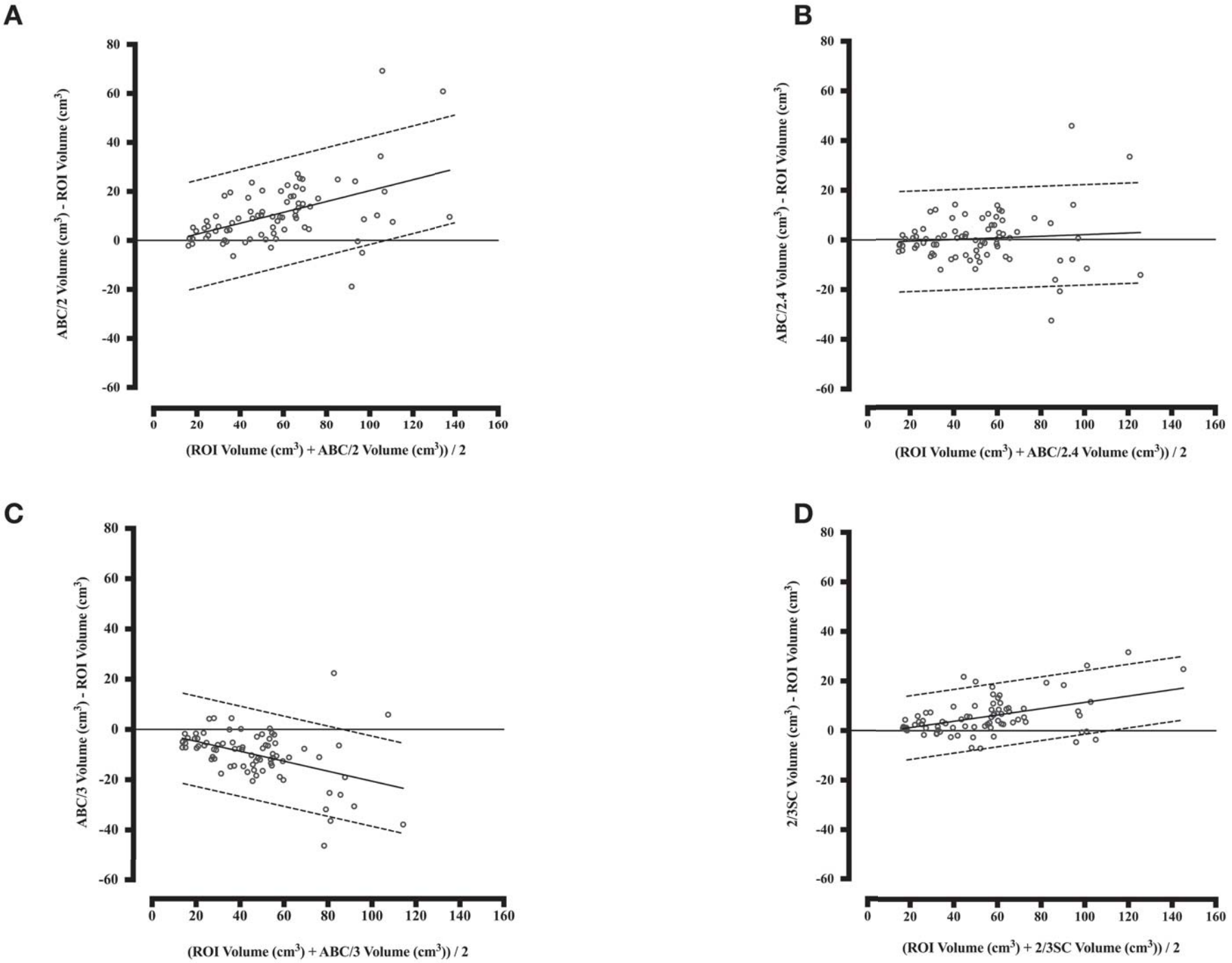
	All patients (n=390)	**Patients with Randomisation scan (n=374)**	**Patients post surgery with ICH on 3-7-day (n=206)**	**Patients with antithrombotic associated ICH (n=79)**	**Patients with Irregular shape ICH (n=386)**	**Patients with Irregular density ICH (n=370)**
Age Mean (SD)	65.2 (12.9)	65.6 (12.6)	65.3 (12.5)	69.2 (10.2)	65.2 (12.9)	65.2 (12.8)
Male (%)	209 (53.6)	198 (52.9)	104 (50.5)	43 (54.4)	206 (53.4)	197 (53.2)
Glasgow Coma Score						
3-8 (%)	12 (3.1)	11 (2.9)	10 (4.9)	2 (2.5)	12 (3.1)	12 (3.2)
9-12 (%)	124 (31.8)	120 (32.1)	68 (33.0)	23 (29.1)	123 (31.9)	117 (31.6)
13-15 (%)	254 (65.1)	243 (65.0)	128 (62.1)	54 (68.4)	251 (65.0)	241 (65.1)
Hypertension (%)	255 (65.4)	248 (66.3)	137 (66.5)	58 (73.4)	252 (65.3)	243 (65.7)
On hypertension medication (%)	189 (48.5)	183 (48.9)	99 (48.1)	52 (65.8)	188 (48.7)	180 (48.6)
Previous myocardial infarction (%)	26 (6.7)	26 (7.0)	16 (7.8)	18 (22.8)	25 (6.5)	25 (6.8)
Previous stroke (%)	54 (13.9)	50 (13.4)	30 (14.6)	17 (21.5)	54 (14.0)	53 (14.3)
On Anticoagulation (%)	37 (9.5)	37 (9.9)	17 (8.3)	37 (46.8)	37 (9.6)	36 (9.7)
On antiplatelet (%)	53 (13.6)	51 (13.6)	29 (14.1)	51 (64.6)	53 (13.7)	52 (14.1)
On thrombolytic (%)	5 (1.3)	5 (1.3)	3 (1.5)	5 (6.3)	5 (1.3)	5 (1.4)

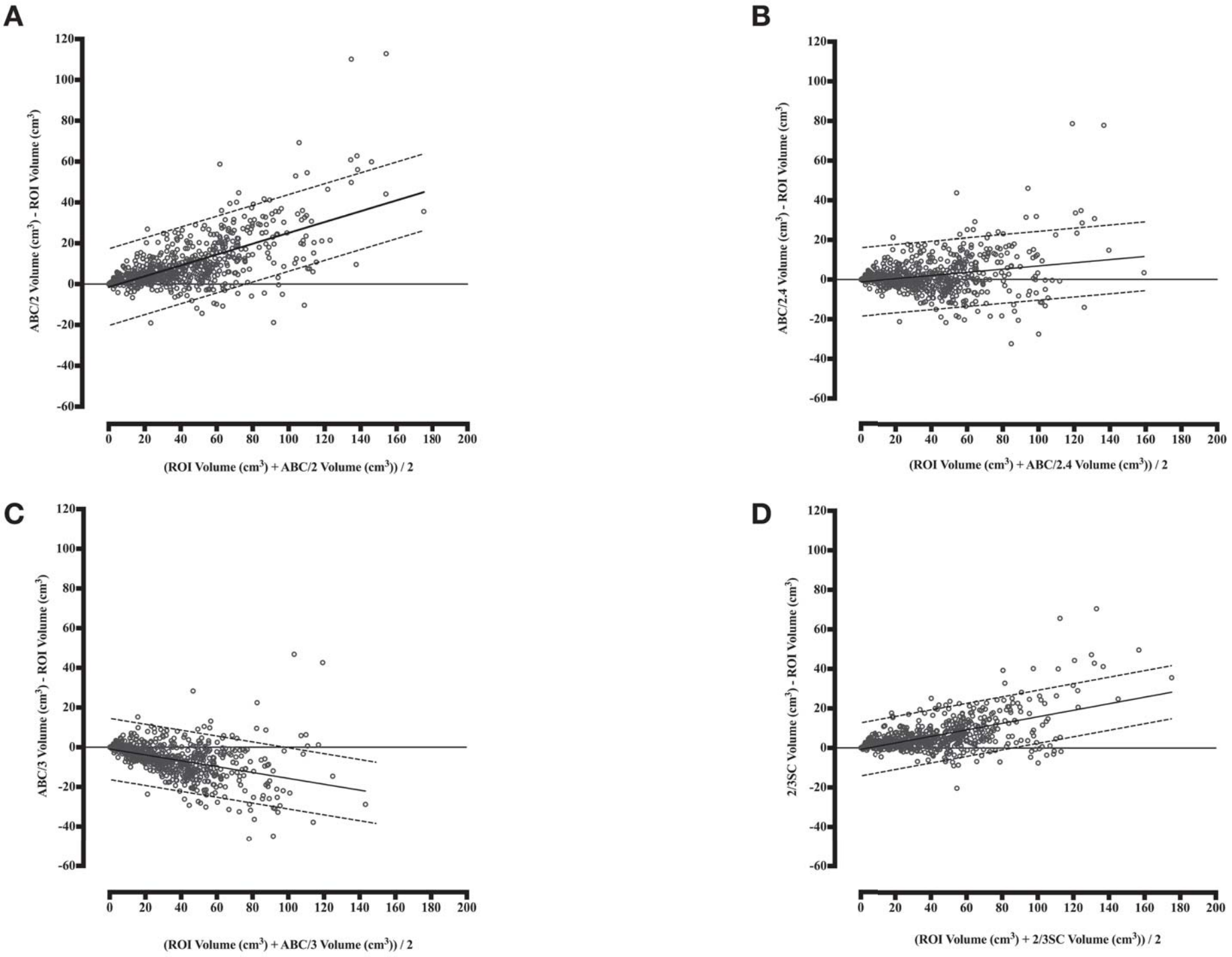
Table 2 Characteristics of included scans. Data are mean (Standard Deviation, SD), median (Interquartile Range IQR, Range) or frequency (%).

	All Scans (n=739)	**Randomisation scans (n=374)**	**Post op Scans (n=206)**	**Antithrombotic associated Scans (n=79)**	**Irregular shape Scans (n=703)**	**Irregular density Scans (n=650)**
Side						
Left (%)	394 (53.3)	199 (53.2)	106 (51.5)	31 (39.2)	371 (52.8)	339 (52.2)
Right (%)	342 (46.3)	174 (46.5)	98 (47.6)	48 (60.8)	329 (46.8)	309 (47.5)
Bilateral (%)	3 (0.4)	1 (0.3)	2 (1.0)	0 (0)	3 (0.4)	2 (0.3)
Deep (%)	190 (25.7)	90 (24.1)	57 (27.7)	24 (30.4)	183 (26.0)	166 (25.5)
Primary Lobe Affected						
Frontal (%)	207 (28.0)	103 (27.5)	59 (28.6)	27 (34.2)	199 (28.3)	183 (28.2)
Temporal (%)	231 (31.3)	114 (30.5)	61 (29.6)	19 (24.1)	218 (31.0)	212 (32.6)
Parietal (%)	237 (32.1)	123 (32.9)	70 (34.0)	19 (24.1)	225 (32.0)	201 (30.9)
Occipital (%)	64 (8.7)	34 (9.1)	16 (7.8)	14 (17.7)	61 (8.7)	54 (8.3)
Region of Interest (ROI) Mean Volume (SD)	35.4 (26.8)	45.6 (24.2)	12.9 (18.5)	51.2 (25.2)	36.2 (27.0)	37.3 (27.2)
Barras Shape Mean (SD)	4.4 (0.9)	4.4 (0.9)	4.42 (0.9)	4.37 (0.9)	4.49 (0.7)	4.5 (0.8)
Barras Density Mean (SD)	4.05 (1.1)	4.07 (1.1)	4.16 (1.2)	4.32 (1.0)	4.14 (1.1)	4.35 (0.8)
Intraventricular Haemorrhage (%)	104 (14.1)	46 (12.3)	36 (17.5)	14 (17.7)	102 (14.5)	94 (14.5)


A
ABC/2 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/2 Volume (cm3)) / 2
B
ABC/2.4 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/2.4 Volume (cm3)) / 2
C
ABC/3 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/3 Volume (cm3)) / 2
D
2/3SC Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + 2/3SC Volume (cm3)) / 2


A
ABC/2 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/2 Volume (cm3)) / 2
B
ABC/2.4 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/2.4 Volume (cm3)) / 2
C
ABC/3 Volume (cm3) -]ROI Volume (cm3)
(ROI Volume (cm3) + ABC/3 Volume (cm3)) / 2
D
2/3SC Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + 2/3SC Volume (cm3)) / 2


A
ABC/2 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/2 Volume (cm3)) / 2
B
ABC/2.4 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/2.4 Volume (cm3)) / 2
C
ABC/3 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/3 Volume (cm3)) / 2
D
2/3SC Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + 2/3SC Volume (cm3)) / 2
80
60
40
20
0
-20
-40
-60
0
20
40
60
80
100
120
140
160

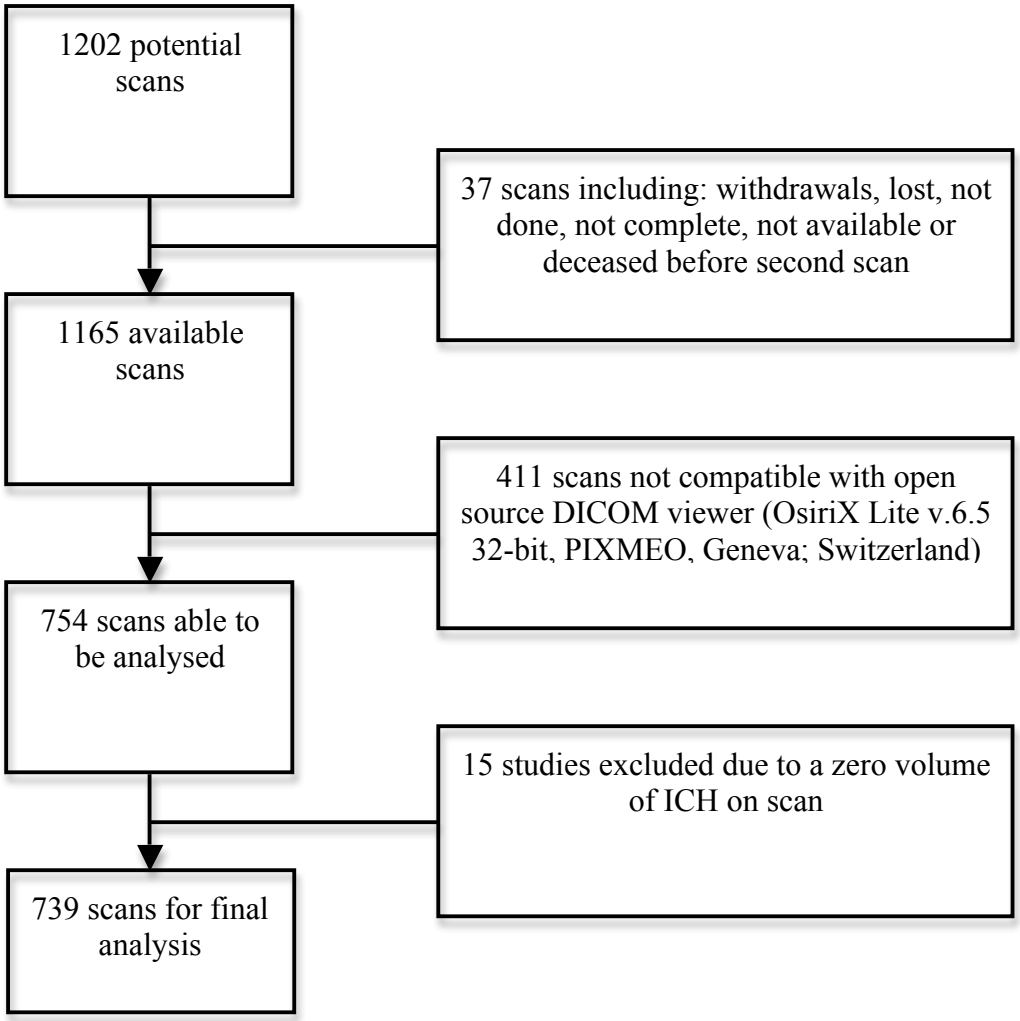

A
ABC/2 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/2 Volume (cm3)) / 2
B
ABC/2.4 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/2.4 Volume (cm3)) / 2
C
ABC/3 Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + ABC/3 Volume (cm3)) / 2
D
2/3SC Volume (cm3) - ROI Volume (cm3)
(ROI Volume (cm3) + 2/3SC Volume (cm3)) / 2

SUPPLEMENTAL MATERIAL

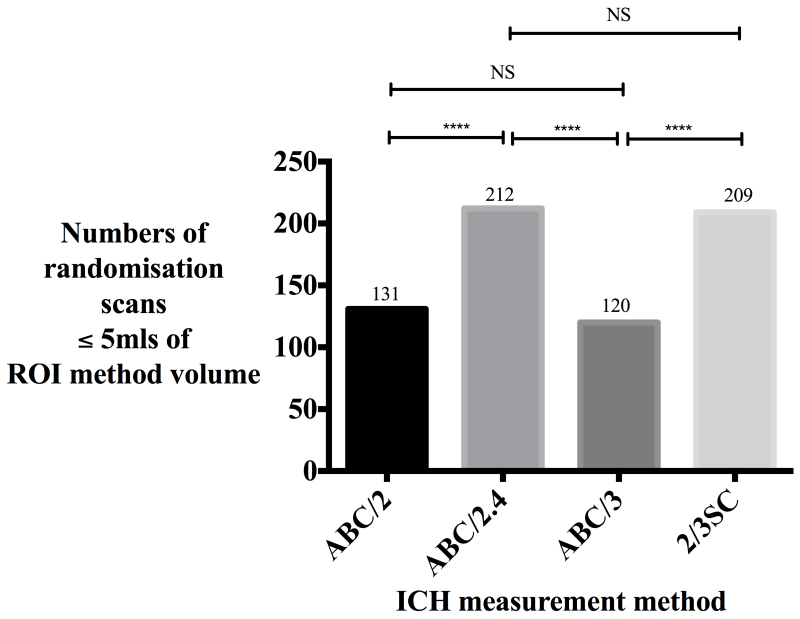
Supplementary Table I: Comparisons of Barras ordinal shape and density scales before and after surgery utilising matched scans (n=195)

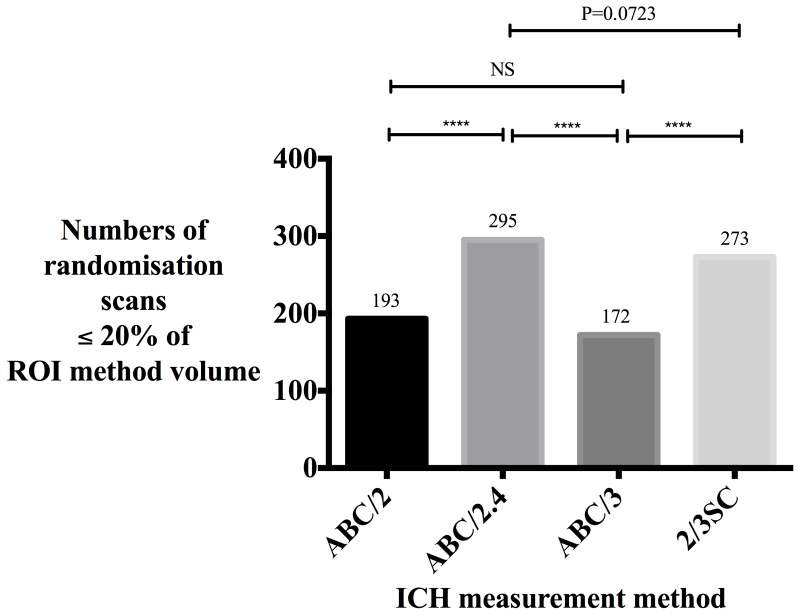
Barras Shape Score	**I**	**II**	**III**	**IV**	**V**	**Totals**
Matched randomisation scans (n=195)	1	7	17	51	119	195
Matched post operative scans (n=195)	3	8	22	35	127	195
Fisher's exact test for significance for change in Barras Shape Score p= 0.298 (p>0.05) There is a non-statistically significant change in Barras Shape Scores between matched randomisation and postoperative scans.						
Barras Density Score	**I**	**II**	**III**	**IV**	**V**	**Totals**
Matched randomisation scans (n=195)	0	14	37	39	105	195
Matched post operative scans (n=195)	6	17	37	16	119	195
Fisher's exact test for significance for change in Barras Density Score p= 0.001 (p<0.05) There is a statistically significant change in Barras Density Scores between matched randomisation and postoperative scans. There is a significant trend to decreasing Barras Density scores post operatively.						

Supplementary Figure I: Patient selection flow diagram



Supplementary Figure II – Number of randomisation scans ≤ 5mls (A) or (B) ≤ 20% of ROI volume. Statistical significance determined using Fisher's Exact Test. (**** = P<0.0001).





Supplementary Figure III: Bland-Altman Plots comparing ICH volume for scans with Barras Density 3-5 measured by region of interest (ROI) volume with ABC/2 (A) ABC/2.4 (B), ABC/3 (C) and 2/3SC (D) measured in centrimetres cubed (cm^3). Linear regression of volume difference on mean volume: (A) y=0.27x-1.5, (B) y=0.08x-1.2, (C) y=-0.15x-0.88, (D) y=0.17x-0.74. 95% confidence intervals constructed by linear regression of residuals: (A) y=0.27x+17.29, y=0.27x-20.27 (B) y=0.08x+16.08, y=0.08x-18.48, (C) y=-0.15x+14.54, y=-0.15x-16.31 (D) y=0.17x+12.69, y=0.17x-14.17